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# (54) COLLECTION RESERVOIR FOR USE WITH FLOW METER CONTROL SYSTEM

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(52) **U.S. Cl.** ....................................... **73/861.12**; 604/22
(58) **Field of Search** ......................... 73/861.12, 861.21, 73/861.18; 128/205, 205.29, 205.27; 604/22; 434/262; 606/48, 40

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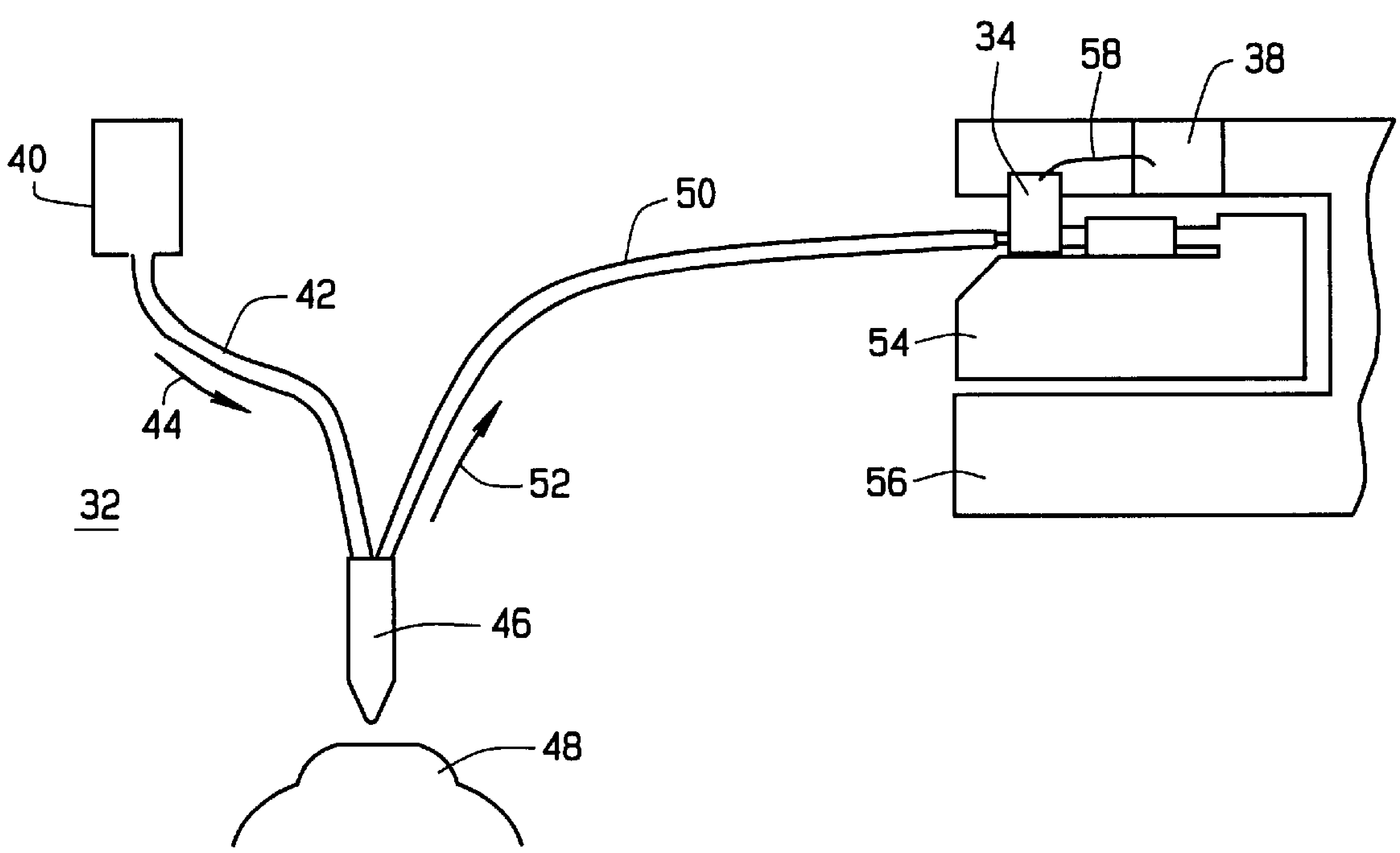
## (57) ABSTRACT

A collection reservoir **54** includes a rigid-walled cassette adapted for connection to aspiration tubing **50**. The cassette also includes a pair of electrodes **36** positioned so that the electrodes are electrically connectable to a flow meter **34**. In operation, the electrodes are exposed to the fluid and tissue being aspirated from the surgical site so that the flow meter indicates a flow rate of the fluid and tissue from the surgical site.

**2 Claims, 1 Drawing Sheet**



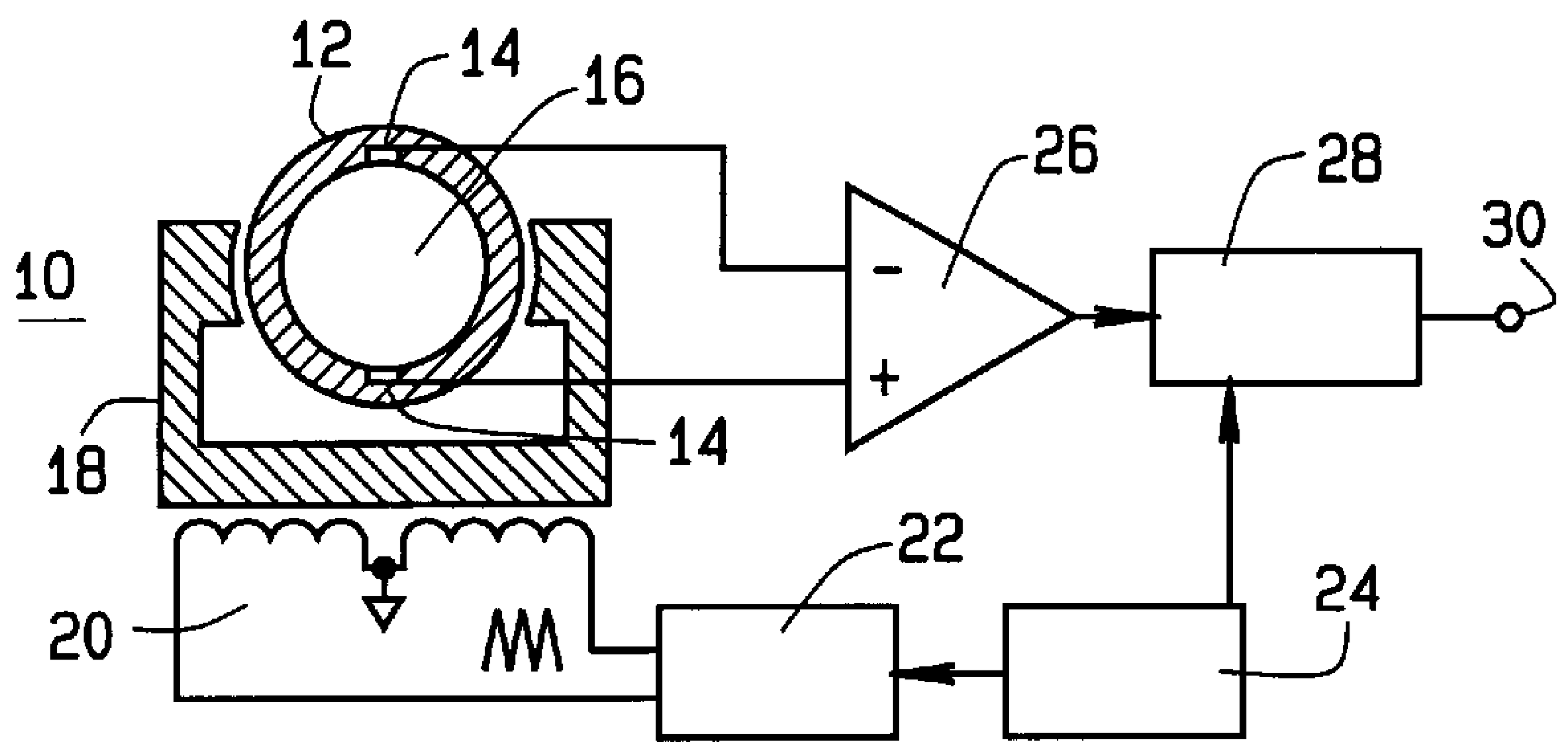



FIG. 1
PRIOR ART

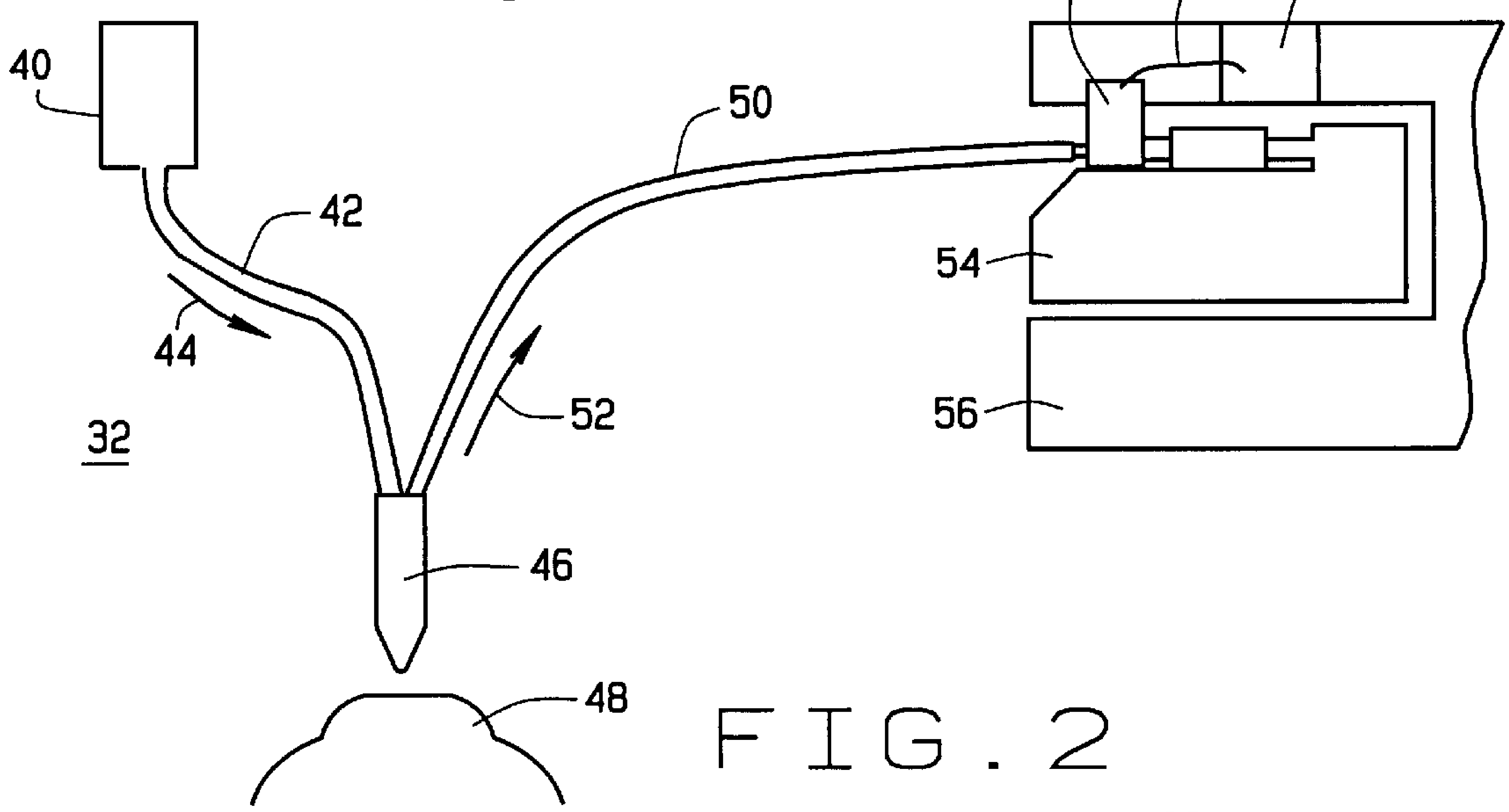



FIG. 2

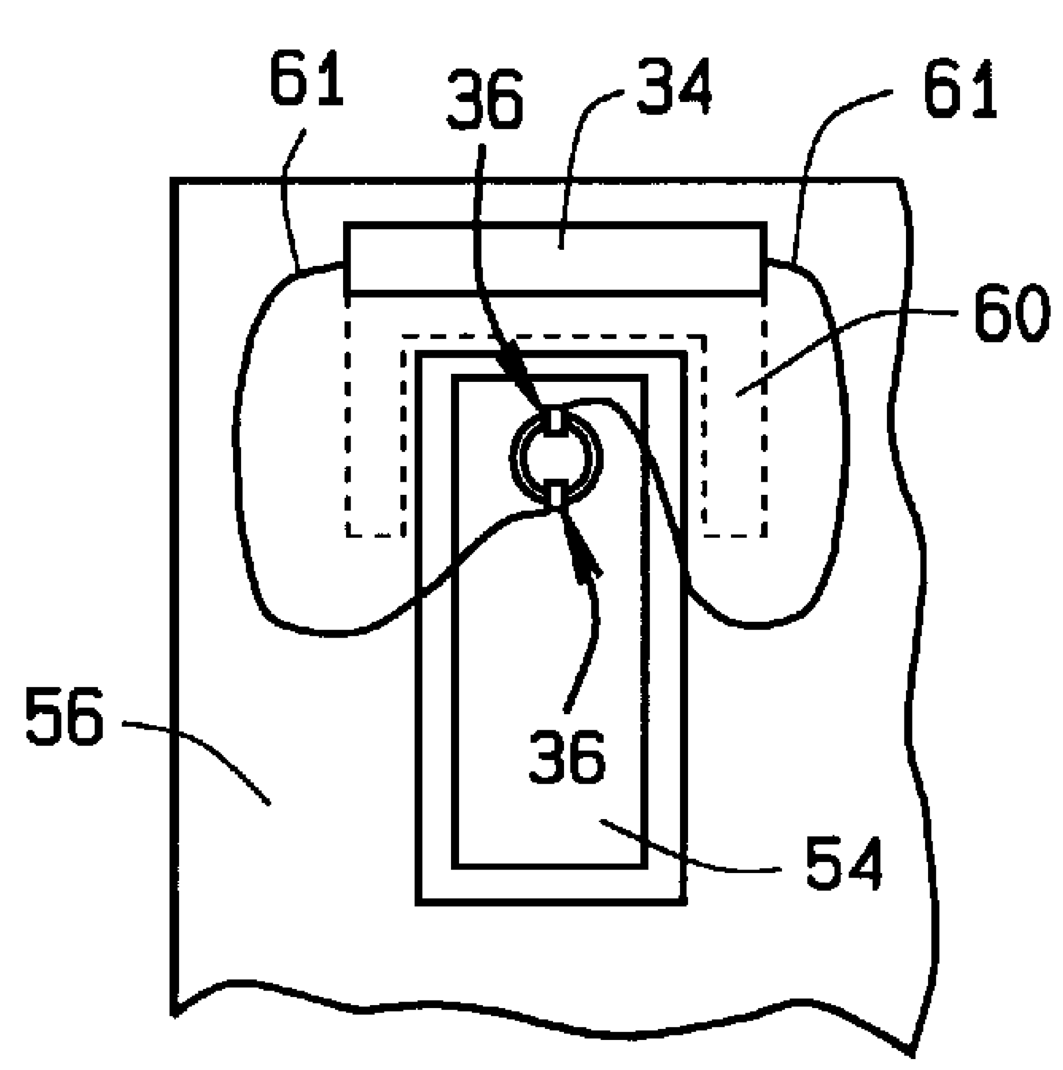



FIG. 3

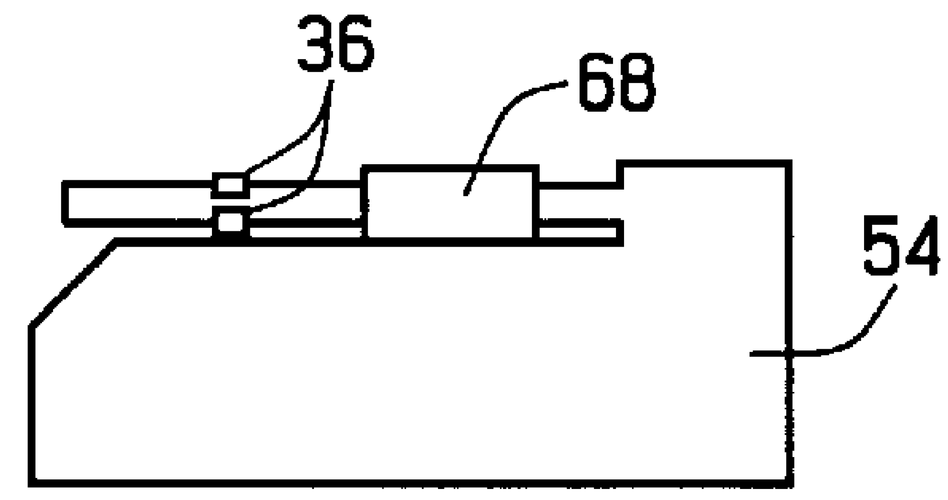



FIG. 4

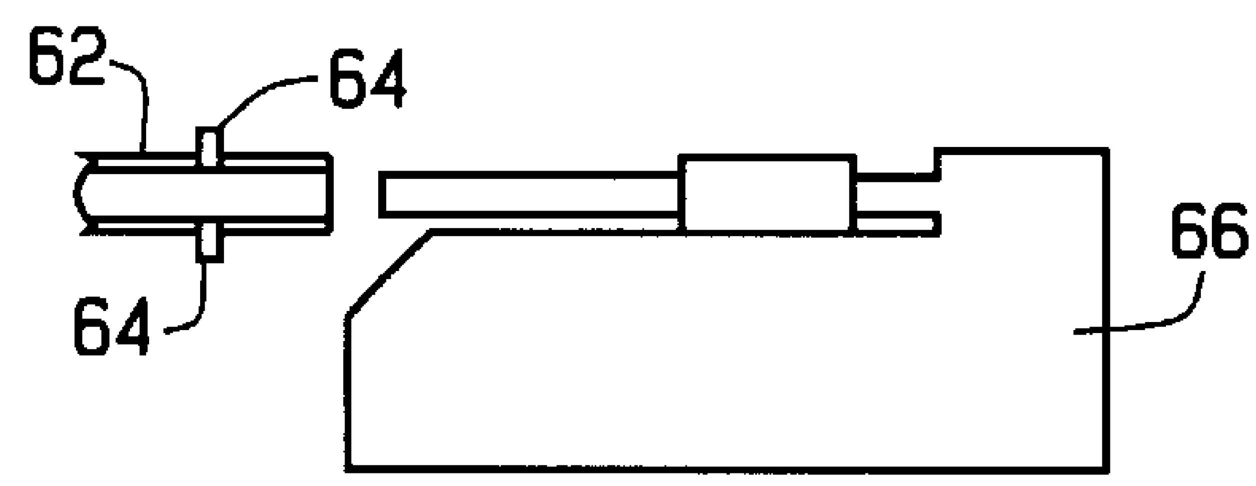



FIG. 5

# COLLECTION RESERVOIR FOR USE WITH FLOW METER CONTROL SYSTEM

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to sensing an aspiration flow rate in a surgical pump system. More particularly, the present invention is directed towards a flow meter and control system for use with surgical pump systems.

2. Description of Related Art

The flow and flow rate of tissue and fluids through an aspiration tube is of interest during operations, including ophthalmic operations. However, direct measurement of the flow rate is typically impractical. Flow rates are generally inferred for positive displacement pumps, e.g., flow-based pumps that are based on pump rotation or other in-direct periodic measurements, these pumps are also commonly referred to as peristaltic pumps. Flow rates for venturi-based pumps have generally not been measured nor has an indirect measurement been used.

Measurement of the surgical aspiration flow rate may be valuable in that it can provide for safe control of the ophthalmic surgical equipment. In most positive displacement-based systems, flow has been known to be inferred from the cycle frequency, i.e., the rotation rate, of the aspiration pump. However, this inference may be invalid in situations where there are varying pressure differentials within the pump system. The pressure variations may occur as a result of changes in the irrigation-fluid bottle height, changes in the viscosity of the aspirant, and changing occlusion conditions at the distal end of the aspiration tube. For known venturi-based aspiration systems no flow measurement has previously been feasible, nor can flow be accurately inferred from the vacuum level. This is because the actual flow rate varies with the viscosity of the aspirant and the occlusion state of the aspiration tube.

In the prior art, it is possible to measure the flow rate in the aspiration tube with a positive displacement or venturi-based system or any other type of pump system using traditional flow sensors. These traditional flow sensors include paddle-wheel, hot-wire, or other devices which are deflected in the presence of fluid flow. However, these devices become contaminated or closed by the aspirant and cannot be reused on a different patient, thereby making the use of such sensors expensive.

Therefore, it would be desirable to have a low-cost flow sensor that could be inexpensively incorporated into a disposable or reusable system to directly measure flow rate. Such a flow measurement can enable new modes of operation, particularly for vacuum-based systems. One such application is the emulation of a flow-based pump by a vacuum-based pump using an additional control loop.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a prior art circuit diagram of a Hall-effect flow meter;

FIG. **2** is a partial cut-away view of a pump system in accordance with the present invention;

FIG. **3** is a front view of a surgical cassette inserted in a console in accordance with the present invention;

FIG. **4**. is a surgical cassette in accordance with one aspect of the present invention;

FIG. **5** is an illustration of an aspiration tube for connection to a surgical cassette in accordance with an alternative embodiment of the present invention.



## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hall-effect flow meters for sensing the flow of conductive fluids are known. Such a prior art Hall-effect flow meter is shown in FIG. **1**. The flow meter **10** includes a conduit **12** including electrodes **14** that are in communication with the inner diameter of conduit **12** such that the electrodes are in contact with conductive fluids **16** flowing through conduit **12**. A magnetic core **18** is placed around conduit **12** so as to induce an electromagnetic field perpendicular to a line-drawn through electrodes **14**. Transformer **20** is connected to driver **22** and oscillator **24**. Signals from electrodes **14** are amplified by amplifier **26**, and the amplified signals are fed to synchronous demodulator **28**. A signal representative of the flow rate of the conductive fluid **16** is outputted to node **30**.

Ophthalmic surgical systems can be broadly categorized as flow-based or vacuum-based. Flow-based pump systems attempt to maintain a constant or controlled rate of flow within specific vacuum ranges. A feedback or control loop may be used to ensure the constancy of the drive system under differing loads conditions. An additional feedback control loop may exist between a vacuum sensor in the aspiration line in the motor, to limit the amount of vacuum in the aspiration tube.

Vacuum-based systems also have feedback control loops, where the signal from a vacuum sensor in the aspiration path is compared to the pre-set desired vacuum level. Error signals are then sent to a vacuum generator, such as a proportional value and venturi chamber, to increase or decrease the vacuum level.

In certain situations, the emulation of a flow-based pump system by a vacuum-based pump system may be desirable. Such emulation has not been practical before the present invention, because there has been no practical means to measure flow rate in the vacuum-based system.

The present invention solution for ophthalmic aspiration flow rate measurement preferably utilizes an isolated Hall-effect electromagnetic flow meter, such as described above in FIG. **1**. The present invention, shown in FIG. **2**, takes advantage of the fact that the saline solution commonly used in ophthalmic surgery is electrically conductive. Thus, a Hall-voltage can be induced across an aspiration tube if a magnetic field is applied. The flow meter **34** (preferably similar to the flow meter **10** of FIG. **1**) in the ophthalmic surgical pump system **32** includes of a magnetic field source or electromagnetic magnet and meter **34** in use is connected to a disposable electrode assembly **36** (as shown in FIGS. **3–5**). Control electronics assembly **38**, preferably responds to the output of flow meter **34**, to control a proportional value or venturi chamber (not shown) of a venturi pump **56** to emulate a peristaltic pump by maintaining a constant flow rate of fluids and tissues through path or tube **50**. The preferred embodiment shows an aspiration tube **50**, but the tube **50** could also be other pathways that allow fluids and tissues to be carried away from the surgical site.

FIG. **2**. further shows an irrigation-fluid bottle **40** connected to an irrigation line **42**, with arrow **44** showing the direction of travel of the saline fluid into handpiece **46**. Surgical handpiece **46** performs a surgical operation on eye **48**. Fluids from bottle **40** and excised surgical tissue are aspirated from eye **48** through aspiration path **50** (which is preferably standard surgical tubing) in the direction shown by arrow **52**. The aspirated fluid and tissue is received by collection reservoir **54** which is contained within pump **56** (preferably a venturi pump though a peristaltic or other pump may be used as well). The venturi pump is preferably the same pump sold with Bausch & Lomb's Millennium®

Ophthalmic Surgical System. Venturi pump **56** creates a vacuum level for aspirating fluid and tissue from the surgical site at eye **48** to the collection reservoir **54**. The flow meter **34** is electrically connected (connection shown at **58**) to control circuitry **38**, as well as being electrically connected to one of the aspiration tubing **50** or the collection reservoir **54** as further described below. Control circuitry **38** is connected to the flow meter **34** and to venturi pump **56** for varying the vacuum level of the pump **56** and thereby maintaining a desired flow rate of the fluid and tissue being aspirated from the surgical site.

Preferably, collection reservoir **54** is a rigid-walled cassette so that the cassette will be operable and not collapse during operation when a vacuum level is applied by the venturi pump **56**. Further collection reservoir **54** is similar to cassettes currently sold by Bausch & Lomb except as modified and described in this invention. Electrodes **36** are not visible in the view of FIG. **2** though may be seen in alternative embodiments in FIGS. **3–5**.

FIG. **3** shows a partial front view of a venturi pump **56** including a collection reservoir **54** for use in surgical pump system **32**. Collection reservoir **54** is preferably a rigid-walled cassette adapted for connection to the aspiration tubing **50** and receives fluid and tissue aspirated from a surgical site. Collection reservoir **54** also includes a pair of electrodes **36** positioned so that the electrodes are electrically connectable to flow meter **34**. During operation, the electrodes **36** are exposed to the fluid and tissue such that the flow meter **34** shall indicate a flow rate of the fluid and tissue from the surgical site. Preferably, electrodes **36** are positioned so that, in operation, electrodes **36** align perpendicular to an electromagnet **60** thereby forming a Hall-effect flow meter. FIG. **4** shows a side elevation view of a collection reservoir **54** as described above. Electrodes **36** may be molded into the reservoir **54** or inserted by any other known method, but in any case, the electrodes should form a sufficient seal with reservoir **54** to prevent fluids from leaking.

FIG. **5** is an alternate embodiment of the present invention, wherein surgical tubing **62** is essentially the same as tube **50** except that tube **62** includes a pair of electrodes **64** for cooperation with electromagnet **60** and flow meter circuitry **34** and is shown to be connectable with a collection reservoir **66**. Surgical tubing **62** carries fluid to or from a surgical site and includes a pair of electrodes positioned within the tubing such that the electrodes, in operation, are exposed to the fluids and wherein the electrodes are electrically connectable to a flow meter for indicating a flow rate of the fluids through the tubing. Preferably, the electrodes **64** are positioned so that, in operation the electrodes are perpendicular to an electromagnet, such as that shown in FIG. **3**, to form a Hall-effect flow meter. Electrodes **64** may be molded into tubing **62** or may be press fit and should form a liquid tight seal with tubing **62**.

The flow meter **34** provides a magnetic field required to produce the Hall-effect voltage. The magnetic driver can be constructed of a permanent or preferably an electromagnet. An electromagnet is preferred so that the magnetic field may be oscillated. Alternatively, the field may be oscillated by rotation of a fixed cylindrical magnet (not shown). In either configuration, an air gap is required so that the aspiration tube may be inserted within the magnetic field. The disposable electrodes **64** or **36** must be in contact with the aspirant. These electrodes may be molded into an aspiration tube **60** as shown in FIG. **5**, into a cassette **54** as shown in **3** and **4**, or into a reflux bulb **68** at low cost. It is also noted that a Hall-effect flow meter as described, can be connected to irrigation tubing **42** to provide an accurate flow rate of the saline solution into the eye.

The metal electrodes **36** or **60** are in contact with the aspirated saline solution resulting in an electrochemical reaction, such as corrosion, which, in turn, produces electrical signals. The use of an alternating magnetic field from the Hall-effect flow meter induces alternating voltages. The amplitude of this alternating field is then correlated to a flow rate. Electrochemical voltages not associated with the flow rate are filtered and eliminated easily because they are steady currents.

Thus, there has been shown an inventive flow meter for an ophthalmic surgical pump system. This flow meter could be used with flow-based pumps or vacuum-based pumps as described above.

Important application using the flow meter **34** in connection with the venturi-based pump system is the emulation of a positive displacement pump. The flow rate output of meter **34** can be used in a feedback control loop to adjust the vacuum level. This feedback control loop is preferably part of control circuitry **38**. This control loop consists of measuring the flow rate with meter **34** and comparing that rate to the commanded flow rate. If the sense flow rate is lower than commanded, a vacuum generator level is increased to generate additional vacuum. This in turn increases the flow rate. Conversely, if the flow rate is too high, the vacuum generator level is decreased resulting in a decreased flow rate. In this way, using control system design the characteristics of a flow-based pump may be emulated using venturi pump **56**. With or without a feedback control loop, it is preferred that the flow rate detected by flow meter **34** be displayed (not shown) by pump system **32**.

An additional application of flow sensor **34** is occlusion detection. Essentially, occlusion detection is simply another flow rate detection scheme where the flow rate detected approaches zero (0) when tissue blocks the tip of a surgical device or the aspiration tube. When the flow rate approaches zero (0) dangerous conditions result such as overheating of the surgical device or occlusion of the aspiration pathway and quick detection of such a condition is highly desirable. Therefore, detection of a flow rate approaching zero (0) could be used to warn the user (audibly or visually) that the system has an occlusion or upon detection the aspiration could be slowed or stopped. As those skilled in the art will appreciate, the detection and warning of a flow rate need not be at zero (0), but could occur at some flow rate above zero (0), but where overheating may still be of concern.

Thus, there has been shown an inventive ophthalmic surgical pump system providing a low-cost aspirant flow meter. In addition, such a system may be used in other surgical pump systems, such as endoscopic pumps.

We claim:

**1**. A collection reservoir for use in a surgical pump system comprising:

a rigid-walled cassette adapted for connection to an aspiration tube and for receiving fluid and tissue aspirated from a surgical site; and

a pair of electrodes molded into the cassette and positioned so that the electrodes are electrically connectable to a flow meter wherein the electrodes, in operation, are exposed to the fluid and tissue such that the flow meter indicates a flow rate of the fluid and tissue from the surgical site without the electrodes interfering with the flow of fluid and tissue through the cassette.

**2**. The reservoir of claim **1** wherein the electrodes are positioned so that, in operation, the electrodes align with an electromagnet thereby forming a Hall-Effect flow meter.

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